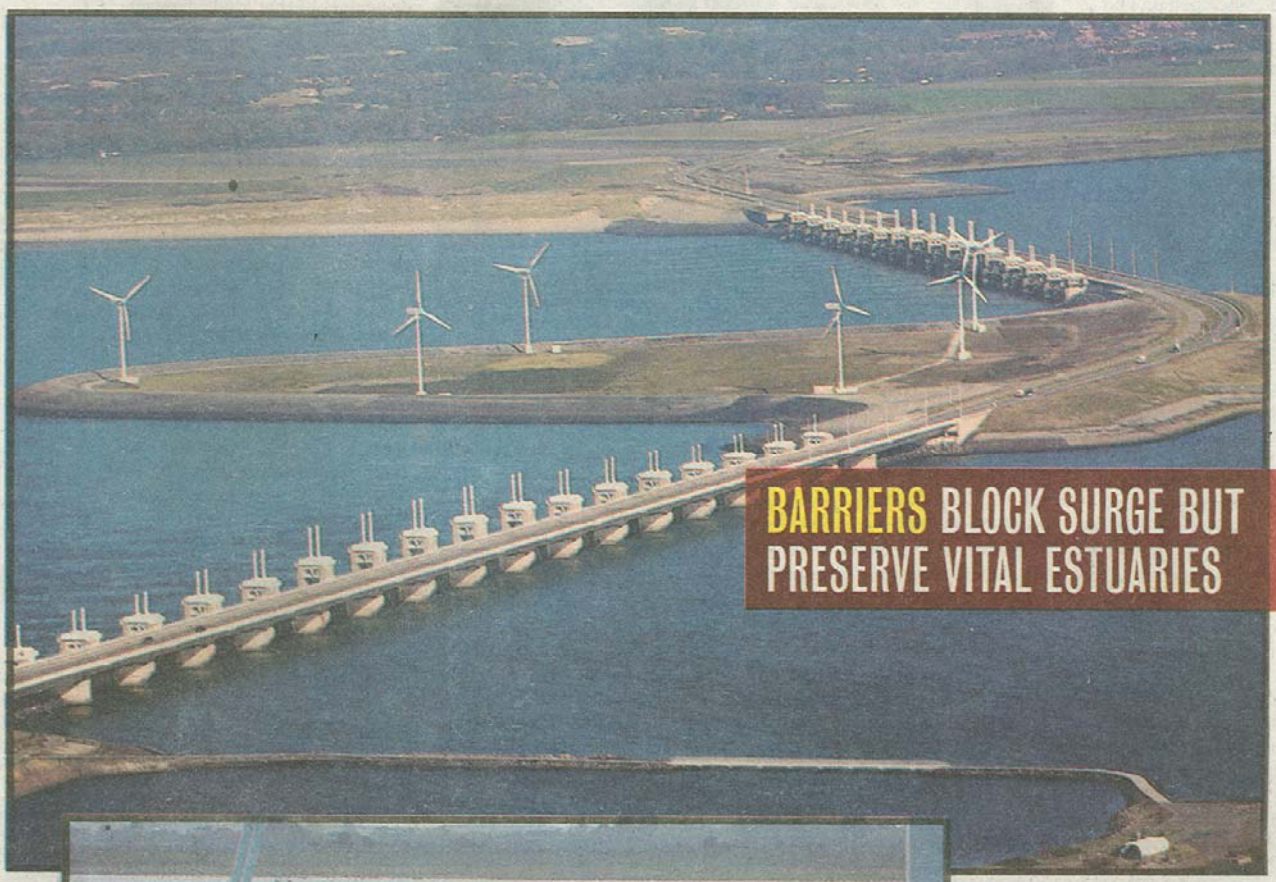
PART 1 OF 3

Beating back the sea

HOW THE DUTCH FIGHT TO SAVE THEIR LOW-LYING LAND



BARRIERS BLOCK SURGE BUT PRESERVE VITAL ESTUARIES

DAMS KEEP OUT THE SEA AND CREATE LAND AND LAKES

PUMPS WORK DAY AND NIGHT TO KEEP LOW AREAS DRY

IN A NATION WHOSE NAME LITERALLY MEANS 'COUNTRY BELOW THE EARTH'S SURFACE,' IT'S NO WONDER FLOOD CONTROL IS AN OBSESSION

After a North Sea flood killed nearly 2,000 people in the Netherlands in 1953, building a state-of-the-art flood defense became a national priority. See story, A-8

INSIDE

▶ A look at the massive dams, gates and storm barriers of Holland, A-9

MONDAY

▶ Gigantic structures rise from the sea to stop storm surge before it hits land.

COMING

▶ Environmental damage led to new dams that now protect wildlife and estuaries.

TER HEIJDE, NETHERLANDS

The North Sea's furious winters can kick up storm surges more than 13 feet high – a lethal threat to a country where millions live below sea level, some as much as 22 feet down. And the Dutch have devised a peerless system of flood defenses – one of the world's engineering marvels – to keep that water out.

Giant barriers straddle ocean inlets, their gates poised to slam shut to repel the invading sea. Massive earthen dams run for miles, blocking off vast areas once open to the North Sea, now converted to freshwater lakes and new living space.

Those are among the master strokes. But the Dutch system is also noted for its subtlety. The only thing lying between the tiny red-roofed village of Ter Heijde and the sea, a scant 200 yards away, is a big pile of sand.

It's no ordinary dune, however. Monitored and maintained with obsessive care, it's built to absorb pounding blows from ocean waves. It may erode, requiring repair, but it won't fall down. It's engineered to fail less than once every 10,000 years, making it 50 times safer than the New Orleans levees were supposed to be before Hurricane Katrina overwhelmed them.

But authorities aren't complacent about those numbers. Concerned about projected sea level rise, the government is studying how to further fortify the dune. "It's adequate, but we do know we will need more protection for the future," Ter Heijde native Jacqueline Voois said. "Growing up here, you learn you can't trust the sea."

The Netherlands' flood defenses – a sculpted landscape of dunes, dikes, dams, barriers, sluices and pumps designed to repel the twin threats of ocean storm surges and river flooding – are light years ahead of the New Orleans area's busted-up levee system.

See **NETHERLANDS,** *A-8*

RUIN & RECOVERY

An occasional series on how others responded to disaster

Stories by John McQuaid
Staff writer

Photos by Michael DeMocker
Staff photographer

Dutch philosophy: Let water ebb, flow

NETHERLANDS, *from A-1*

As American policymakers and the Army Corps of Engineers study how to rebuild the levees to protect against a Category 5 hurricane, Dutch engineers say they can learn a lot from the Dutch model, where all elements – from structural engineering to long-term policymaking – fit seamlessly together.

NETHERLANDS
ONCE IN 10,000 YEARS*
Projected failure rate

NEW ORLEANS
ONCE IN 200 YEARS*
Projected failure rate

* Estimated occurrence of a storm that would overwhelm the flood-protection system.

"Your levee system doesn't appear to have been designed as a system. It's designed in a very haphazard way. One structure built one way, one built another," said Jurjen Battjes, a professor emeritus of engineering at the Technical University of Delft and a member of the American Society of Civil Engineers team investigating the New Orleans levees.

"They can move vehicles on Mars. Why should your system fail because of a wall collapsing or because an operator left the pumping station?"

There was a time when New Orleans led the world in flood control and the Netherlands looked west for guidance, importing the huge screw pumps designed by Albert Baldwin Wood that had drained low-lying areas and greatly expanded New Orleans' habitable turf. Today, the Dutch system offers a trove of examples, from policy ideas to engineering fixes, that could be useful to New Orleans. Indeed, U.S. Sen. Mary Landrieu next month will lead a delegation of Louisiana officials and congressional colleagues to the Netherlands to study them.

Like New Orleans, which built up its river levees after the 1927 flood and its hurricane levees after Betsy in 1965, the Dutch system has been forged in disaster. But the Dutch have a lot more disaster experience, and it shows.

For the past 1,000 years they have sculpted and resculpted their landscape to repel floods, only to see it repeatedly inundated – most recently by a 1953 North Sea storm surge that killed more than 1,800 people. Each time, they have rebuilt bigger, better and with greater sophistication. Flood protection is the No. 1 national priority, and that is reflected not only in dikes and barriers but in politics, budgets and the concerns of everyday citizens.

Their philosophy, shaped by centuries of combating floods, is to fight water – but also to accommodate it rather than just contain it, preserving natural flows where possible. "There's one important lesson we've learned as Dutch – we're fighting a heroic fight against nature, the sea and the rivers," said Ted Sluijter, a spokesman for the giant Eastern Scheldt storm surge barrier. "But if you fight nature, nature is going to strike back. Water needs space."

A massive gate that is part of the Maeslant storm barrier protects the Rotterdam Waterway, a shipping channel that leads from the North Sea into Rotterdam, Netherlands. Without its elaborate network of flood control structures, 65 percent of the Netherlands would be underwater.

Newly planted marram, a grass that is widely used to hold dunes together, grows atop the dune protecting the small seaside town of Ter Heijde, Netherlands. The dune, which is regularly monitored and maintained, is expected to fail less than once every 10,000 years.

The Netherlands learned such lessons by trial and error over the centuries. To a far greater extent than in the United States, citizens' lives depend on flood defenses. Studies show that without its elaborate network of flood control structures, 65 percent of the country would be underwater.

The Dutch Ministry of Water, Public Works and Transportation spends $1.5 billion a year on flood defense and water management. If the United States spent that much on a per-citizen basis, it would cost upward of $30 billion annually, seven or eight times the Corps of Engineers' annual budget of $4 billion.

Sinking and sinking

The country's most densely populated region is built on what used to be low-lying marshes. Three rivers flow out to the North Sea through the Netherlands: the Rhine, the Meuse and the Scheldt. For millennia the western part of the country consisted of estuaries and peat bogs repeatedly reshaped by floods and tides.

But somehow the forebears of today's Dutch settled these areas, leading a precarious existence on natural or man-made ridges.

"There the ocean throws itself, two times a day, daily and nightly, in a tremendous stream over a wide country, so one doubts if the ground belongs to the land or to the sea,"

See **NETHERLANDS,** *A-10*

Barriers, dams at sea relieve pressure on levees

NETHERLANDS, *from A-8*

wrote Roman philosopher Pliny the Elder, who as a soldier in the first century A.D. helped construct a canal in what would become the Netherlands. "There lives a miserable people at the highest known levels of the tide and here they have built their huts, living like sailors when the water covers their environment and as if shipwrecked when the water has gone."

Around 1000 A.D., Europe's population swelled and farming expanded. The Dutch began to use limited technologies and their own ingenuity to drain the swamps and keep them dry. Over the centuries, the tools grew more sophisticated, and more and more polders — drained areas ringed by dikes — were created.

But draining peat bogs has one major drawback: They sink. Peat and clay soils contract when drained. The lower they get, the more susceptible they become to floods. The increased flooding in turn made people dig their drainage ditches and canals ever deeper, a vicious cycle that continues today. The problem, compounded by the loss of silting from rivers now controlled by dikes, is similar to the subsidence plaguing the New Orleans area.

Combined with gradually rising seas, the change is shocking. In 900, the Netherlands averaged more than 12 feet above sea level. By 1500, it had dropped even with the sea. Today, it averages 8 feet below sea level and is still dropping at the rate of a quarter-inch each year.

Battles won by the sea

sea has shaped its history, and every six generations or so has been marked by a terrible defeat, a catastrophic flood that has swept over swaths of the country, destroying dikes, homes, property and human lives. The Dutch landscape is dotted with reminders of past floods and the measures taken to ensure such a disaster would never happen again.

The only thing left of Koudekerke, a village overlooking an estuary of the Scheldt, is the Plompe Toren, a brick church tower that casts a lonely silhouette over nearby farms. A 16th-century flood swept away 13 villages, Koudekerke among them. The tower was all that remained. Later rebuilt, it was leveled again during World War II and permanently abandoned. A recording in the tower tells the legend of a merman who cursed fishermen from the village for catching his wife.

Visible to the east is a breached dike from the 1953 flood that was never repaired; authorities instead opted to rebuild farther back from the water. The area behind the breach is now a marsh. Visible to the west is the enormous Eastern Scheldt storm barrier that blocks North Sea surges from the estuary.

Completed in 1986, as part of $14.7 billion in post-1953 improvements, the Eastern Scheldt barrier is a monument to the Netherlands' innovative approach to flood control and includes features the corps is looking at for New Orleans.

Shortening the defenses

For centuries, the Dutch protected themselves by ringing settled areas and farmland with dikes, essentially the same approach used in south Louisiana. But the 1953 flood revealed a big weakness in that strategy: Storm surge water could move far inland through the estuaries, which were open to the sea.

This was also a key failing of the New Orleans system, Battjes and other Dutch engineers say: The region's levee-lined canals were conduits for Katrina's storm surge to pour into

See **NETHERLANDS,** *A-12*

Dutch try a new line of defense, use levees as backup

NETHERLANDS, *from A-10*

the heart of the city. From the east, water flowed into the Intracoastal Waterway and Industrial Canal, where floodwalls were topped and then collapsed, flooding the Lower 9th Ward, St. Bernard Parish and eastern New Orleans. From Lake Pontchartrain, it flowed into the 17th Street and London Avenue drainage canals, which were breached, flooding central New Orleans.

In the wake of the 1953 flood, engineers and policy-makers presented the Netherlands with a choice: They could build dikes higher and stronger as they had always done in the past. Or they could take a different, more ambitious approach, building large barriers across estuaries and other open waterways.

The second option had one crucial advantage: It would effectively shorten the country's tortuously long coastline by hundreds of miles. If the length of the country's defensive barrier shrank, the thinking went, so would the chance that a dike might fail at some unnoticed weak point and lead to a larger catastrophe. Many miles of older dikes would become secondary, backup protections.

"It's much more logical to shorten your line of defense," said Battjes, the retired engineering professor, who advised the new system's designers. "To make a military analogy, the water is the enemy. You don't let the enemy, before the fight starts, penetrate your territory."

Installing surge gates

American engineers have begun looking at how to address this problem in a Category 5 design. One solution would be to put floodgates on some canals. Another would be to retool New Orleans' generations-old stormwater drainage system and move pump stations from the middle of town to the lakefront.

Installing surge gates

American engineers have begun looking at how to address this problem in a Category 5 design. One solution would be to put floodgates on some canals. Another would be to retool New Orleans' generations-old stormwater drainage system and move pump stations from the middle of town to the lakefront.

On a more ambitious scale, some officials suggest upgrading an old proposal to build a large levee and floodgate system across the marshes to block surges from entering the Chef Menteur and Rigolets passes into the lake. An early version of the plan was abandoned after environmentalists raised questions about impacts on marshlands.

The Netherlands example provides a template for how to go about this. Early Delta Works plans called for dams to be constructed across all the region's estuaries — just as the government had dammed off a 20-mile opening along the northern coastline in 1933, creating a giant freshwater lake. But by the 1970s, environmentalists, commercial fishing organizations and other groups were complaining that the completed dams were ruining the region's ecology.

They sparked a national debate and eventually a compromise, one that balanced storm defenses against harm to the environment.

The largest result of the change is the enormous Eastern Scheldt storm surge barrier, a massive series of 62 floodgates snaking across the water. The gates, which range from 19 to 29 feet high, depending on their position on the barrier, are left open most of the time to allow tidal flows in and out, preserving the estuary behind it. When the high-water alarm sounds – as it has on average twice a year since it opened – the gates are shut until the danger passes.

Thinking big from start

As a reminder of why the barrier is there, the height of the 1953 flood – about 13 feet – is marked by a thick red line at a point along the barrier's southern endpoint.

That reminder is also imbedded in the design DNA of every flood protection project in the country in the form of very high, legally mandated safety standards – something New Orleans most assuredly did not have.

The biggest flaw of New Orleans' pre-Katrina levee system was that it provided a low level of safety: It was built only to withstand storm surges from some, but not all, Category 3 hurricanes and was virtually guaranteed to fail in a stronger storm. In retrospect, engineers say it didn't even live up to its Category 3 billing. In fact, no one knew precisely what level of safety it provided because of its many weak points, changes in the landscape over time and the corps' outdated assessments.

Such problems are inconceivable in the Netherlands. Urbanized areas of the country – such as the region surrounding Ter Heijde, which includes The Hague and Rotterdam – are engineered to withstand the kind of storm surge that comes only once in 10,000 years. More sparsely populated areas, such as those protected by the Delta Works, are safe against a 1-in-4,000-year flood. The lowest level of protection, found in rural areas, is for a 1-in-1,250-year flood. All are many times safer than New Orleans ever was.

Feeling safer

Those numbers are more than risk calculations. In a sense, they're as much the bedrock of the nation's flood security as any dike or barrier. Everybody knows those numbers. They reassure citizens, many of whom now take sound flood protection for granted.

"We feel safe – nobody is afraid. Nobody's thinking, 'When is the water coming?'" said Andre van der Beek, a home care worker in Nieuw-Lekkerland, who paused from riding his bike near a line of 200-year-old windmills and two pumping stations, all built to keep water levels down. "There are a lot of believers here, and they believe the story of Noah, that God promised in Genesis there would not be another flood."

But the water is still rising, and the land is sinking, and because of those changes in the landscape, Dutch officials say that some dikes and other parts of the system no longer meet the standards. So they are giving the whole thing a top-to-bottom review to identify emerging weaknesses. Vigilance, they say, must be eternal.

"We are not going to allow the level of protection to decrease," said Marion Smit, the Water and Transportation Ministry's top water policy official.

Achieving that long-term resoluteness might prove to be the single greatest challenge facing New Orleans. Flood control is a national religion in the Netherlands. In 49 U.S. states, it's Louisiana's problem.

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Beating back the sea

HOW THE DUTCH FIGHT TO SAVE THEIR LOW-LYING LAND

DRAINAGE INNOVATION

Wood Screw Pump

INVENTED 1913

A single invention, the screw pump devised by N.O. engineer A. Baldwin Wood, played a central role in shaping modern New Orleans and the Netherlands.

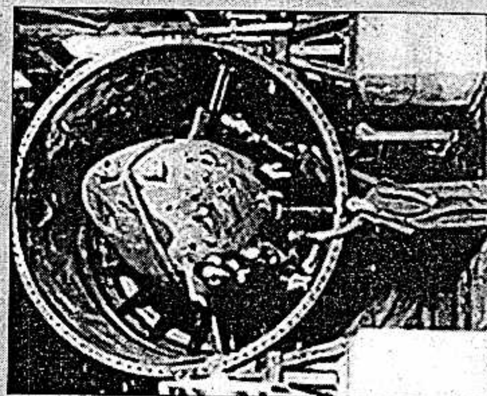
Story by John McQuaid
Staff writer

The newly created Sewerage & Water Board hired Wood fresh out of Tulane University in 1899 to help solve New Orleans' drainage problems, according to a 1974 account of Wood's life from the board.

This was no easy task – the city was inundated by frequent heavy rains and floods, and its pumping system was not up to the challenge. But Wood went about his business with gusto, inventing new pumps and devices such as flap gates that allowed water to exit a channel without flowing back. He acquired 38 patents.

In 1913, Wood invented the 12-foot screw pump. It was based on the ancient Archimedes screw, a simple machine that siphons water up an incline. "This pump, then the biggest and most powerful in the world, later made New Orleans the mecca for the world's engineers," the history says.

The city installed the 12-foot Wood pumps in its pump stations, later adding 14-foot pumps he designed. The results were revolutionary. Newly drained areas could be settled and roads constructed. Disease rates fell because fetid canal water could be pumped out much faster.



STAFF FILE PHOTO

A. Baldwin Wood stands near one of his screw pump creations – and some flappers – in 1928.

Approximately 50 Wood pumps remain operational in New Orleans today.

Wood's pumps and other inventions drew worldwide attention, and he helped design drainage systems in Chicago and Milwaukee, as well as in Egypt, China, and India.

In 1916, Dutch officials approached Wood, seeking his advice on the biggest land reclamation project in Netherlands history, the Zuiderzee Works in the northern part of the country.

As the story goes, the Dutch asked Wood to come to the Netherlands, an invitation he curtly declined. If they wanted to see his work, they could do the traveling, Wood said. The Dutch traveled.

Back in the Netherlands, they dammed the inland Zuider Sea, cutting it off from the North Sea and creating a large freshwater lake. When the dam was complete, engineers built two large pumping stations using Wood's designs. They were used to drain two large areas, creating new polders for agriculture and human settlement.

SIZING UP

The Netherlands, although its own nation, is about half the size of Louisiana

Source: Staff research

STAFF MAP BY DAN SWENSON

1,835 DEAD. 43,000 HOMES DAMAGED. 70,000 EVACUATED.

IN 1953, A CATASTROPHIC FLOOD DECIMATED THE NETHERLANDS' EXTENSIVE SYSTEM OF DIKES AND DAMS.

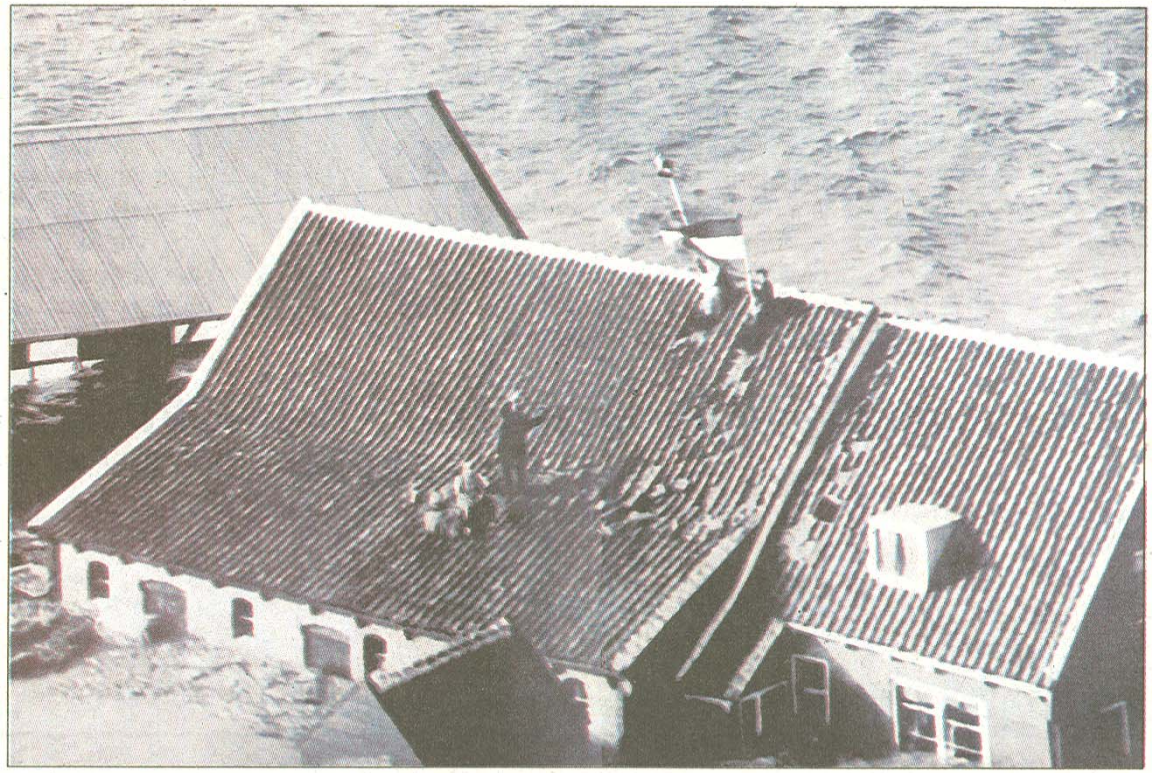
The Dutch swore it would never happen again.

By John McQuaid
Staff writer

OUWERKERK, NETHERLANDS — In the early morning hours of Feb. 1, 1953, a huge storm surge struck the Dutch coastline. Though it was midwinter and far from the tropics, the dome of water was driven by a North Sea storm that had many characteristics of a hurricane. With 60-mph winds blowing clockwise around the storm's central "eye," a spring tide had pumped up the surge to record heights approaching 14 feet.

Gales pushed the surge dead on the Netherlands' most vulnerable spot, its southwest coast — an archipelago of low-lying islands and polders, drained areas ringed by dikes. Dotted with dozens of cities, towns and farms, the area was home to hundreds of thousands of people.

Water flowed far inland through open estuaries and penetrated hundreds of smaller open conduits, including shipping channels and canals. Many dikes were topped and then breached. Others, brutally pounded for hours by waves, simply collapsed. Walls of water poured into inhabited areas. Most residents had no warning before the water reached their doorsteps.



Villagers on the Dutch coast wave from a rooftop seeking rescue after a massive storm-generated flood in 1953.

It was the start of the worst disaster in modern Dutch history. More than 1,800 people died, and hundreds of thousands were displaced by the flood that followed. Photographs from the time — water pouring through dike breaches, thousands stranded on rooftops, piles of waterlogged corpses — eerily foreshadow New Orleans' recent traumas.

But the 1953 flood also sparked a push to rebuild that offers hope for New Orleans. It deeply scarred the national psyche, and after the waters receded, Dutch authorities vowed to reinvent the nation's flood defenses to prevent such a disaster from ever striking again. The result, completed less than a decade ago, is the Delta Works, a $14.7 billion network of barriers, dams and other structures designed to repel North Sea storm surges.

The catastrophe reverberates today in debates about the Netherlands' long-term safety and in the memories of its victims, who remain

See **FLOOD,** *A-11*

Disaster spurs an unprecedented response

FLOOD, *from A-8*

important political voice in shaping flood-control policies.

The 1953 Flood Museum in Ouwerkerk, opened two years ago to mark the disaster's 50th anniversary, is behind a repaired, 1,400-foot dike breach and is housed in a World War II-era U.S. military caisson, a large, reinforced-concrete structure that was used to patch the hole.

'Roaring wall of water'

Pieter Flokweert was 16 at the time of the flood, the elder of two sons of a farmer in the town of Nieuwerkerk, about three miles from Ouwerkerk. He said he and his family had heard radio reports about the storm hitting the English coastline, where it also did great damage, so they expected trouble. On Sunday morning about 5, church bells started ringing.

"The wife of the man in charge of the local water board told us we had to get the hell out of there," Flokweert said. "Men were going with all kinds of equipment – spades, bricks – to get to the dike, which was on the verge of breaking. Five minutes later, our feet were getting wet. The dike was already breaking."

Flokweert and his family shooed their animals out of the barn and retreated to the attic of their house. About 11 a.m., the dike breach widened and water started rising fast. It converged with the flow from another breach as it coursed through town, eventually reaching a height of more than 12 feet.

"At 2 o'clock in the afternoon, we saw the first houses collapsing around us. By 4 o'clock, the whole area was devastated," he said. "We saw a neighbor's house collapse. Its inner walls gave way, then the roof lost support and collapsed. A funneling effect caused refuse and debris and people to flow past the house."

Other places were hit far worse. When the dike protecting the town of Stavenisse broke, "a roaring wall of water 12 feet high moved toward the village," according to an account published later that year. "Demolishing the prosperous farmhouses lying in the shelter of the dike, the moving wall carried the ruins of those sturdy buildings into the village, where beams, doors, railings and furniture became battering rams which ultimately shattered the smaller and more frail houses in the narrow streets."

Two hundred residents — virtually the whole population — drowned.

Not down with the ship

As surge water flowed inland up a tributary of the Rhine into the lowest area of the country — 20 feet below sea level — it threatened to burst through a river dike, flooding one of the country's most densely populated areas, including Rotterdam. When the dike began to breach, the mayor of Nieuwerkerk an den IJssel commandeered a river ship and ordered the captain to steer it into the hole. It worked: The ship plugged the breach.

Across the region, thousands of people were stranded. In the hours after the flood, hundreds of fishermen and other local people fanned out over flooded areas in small boats. In the town of Zeirikzee, a few miles away, fisherman Wim Schott van Sluis, then 24, was plying the floodwaters in a rowboat that held seven, ferrying people from their roofs to nearby high ground.

Before the water rose – about 7 feet in his house – he said, he had put his wife and 5-month-old son on his 75-foot mussel dredger in a sheltered navigation channel. Zeirikzee is on high ground, and by late morning the went out there, we saw all the people on rooftops. We didn't expect such a sight coming from the city and high ground."

Rescuers loaded their rowboats on trucks, drove over high ground to points adjacent to flooded villages, ferried people to safety, then drove them to Zeirikzee.

Van Sluis ferried people round the clock for days, his wrists swollen from rowing. He saved 45 of the 100 residents of a village called Kapelle and gathered information about the others to pass on to the living.

"Everything was dead. It was snowing," he said of the scene in the flood zone. "There were all these small single-story houses and people were sitting on the highest point, one leg on either side." A woman van Sluis rescued had just delivered a baby on a pool table.

Nation rises to respond

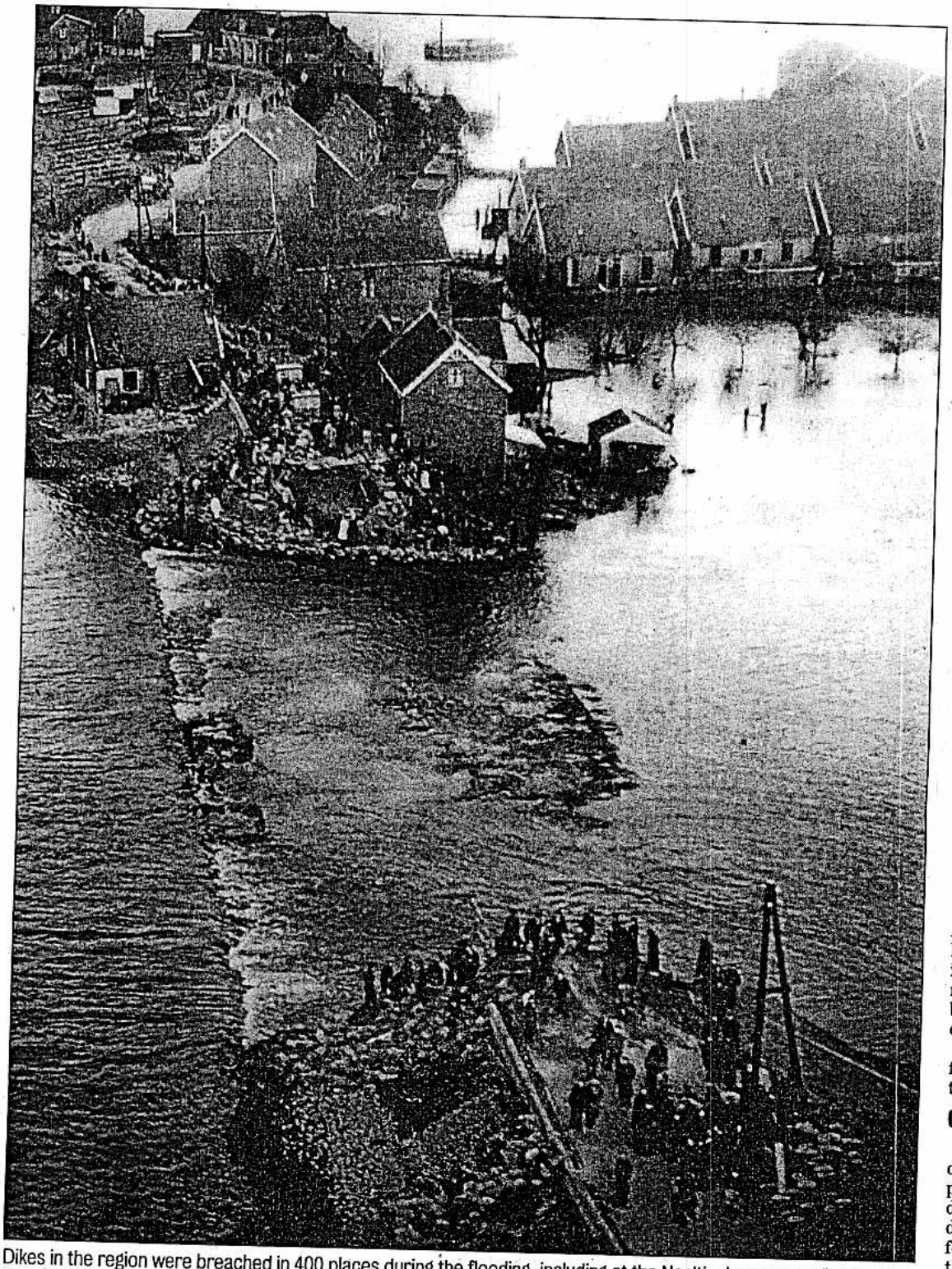
Though communication lines were mostly down, the vast scale of the disaster was clear to Dutch authorities by midday Sunday, and an enormous relief effort was mobilized. Traveling by car, boat, plane and helicopter, Queen Juliana made her way to the disaster zone, donning rubber boots to trudge through the mud and offer support to victims.

In Nieuwerkerk that afternoon, the Flokweert family watched a wind gust turn their barn around and collapse the roof, Flokweert said. "When the barn gave way, waves hit the attic and we realized we could not stay."

"Around 2 a.m., the moon came out a little bit," he said, and it became evident that the flood, once at the eaves of their house, had begun to recede. They waded through icy, neck-deep water to a nearby house on higher ground and joined 18 people who had been crowded into the attic.

The elderly couple who opened their home to neighbors had also opened their clothes closet. "The man was short, chubby and fat, and I was tall and slim," Flokweert said. "His long pants came only to my knees. The waist was twice as big as mine. But I was happy to have them."

On Tuesday morning a fisherman took them to Zeirikzee, which had become a gathering point for refugees. That day, Feb. 3, a huge airlift was begun to evacuate about 70,000 people from the region, an effort that took 10 days.



Dikes in the region were breached in 400 places during the flooding, including at the Neeltje Jans recreational area. The last dikes were repaired nine months after the storm.

Recovering the dead

Flokweert's family remained, however, because he and his father wanted to work. Flokweert got a job on dike repair, while his father worked at identifying corpses. He would bring the photos of decaying, waterlogged bodies home at night.

"It was not a good situation for a young 16-year-old to see all those corpses," Flokweert said. "I still remember the smell of Lysol on him. In hindsight, perhaps we should not have stayed."

They moved about in a moonscape of ruins. The dikes were breached in 400 places, and 67 washed away completely. In all, about 43,000 homes and farms were damaged and 10,000 others were beyond repair, many of those pulverized. Farmlands lay fallow, covered with sand and contaminated by saltwater.

"At 2 o'clock in the afternoon, we saw the first houses collapsing around us. By 4 o'clock, the whole area was devastated. We saw a neighbor's house collapse."

PIETER FLOKWEERT
16 at the time of the flood

The principal economic activities were cleanup and dike repair. Hulking Phoenix caissons that had seen service during the Normandy invasion were brought in from Great Britain, providing the ideal plug for breached dikes.

"The first sign of hope came when I was walking through Zeirikzee in April or May," Flokweert said. "I heard the sound of a dredger clearing the navigational channel and moving in the caissons. Then more big stuff started moving in, heavy equipment."

The dikes were repaired by the following November, nine months after the storm hit.

Call to action

Meanwhile, the nation had begun debating what went wrong. "In the press — in the newspapers the radio, the television — there was a big discussion over who was responsible for this and how can we avoid it for the future," said Kees van der Maas, a retired newspaper editor who as a 15-year-old was evacuated from Zeirikzee after the flood. "Almost everybody came to the conclusion that we have to take some heavy measures."

It took the hard-hit Zeeland region years to get back on its feet. The Flokweerts could not resume farming until 1955.

"People scattered," Flokweert said. "Some found new jobs in evacuation areas and stayed there. Sand covered the agricultural fields and had to be removed." Young people

who might have taken up farming enrolled in schools and never returned.

Today, flood memorials abound in Zeeland. In all, 289 gravestones in the cemetery in Nieuwerkerk commemorate those from the area who drowned, including many in Flokweert's extended family. Granite markers, lying flat on the ground and engraved only with names and birthdates, commemorate the elderly, the middle-aged and the young, including toddlers and babies. Many are marked "VERMIST" – "missing."

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The 1953 flood photos are from "The Battle of the Floods," published by Netherlands Booksellers and Publishers Association in Holland in 1953.

Dutch soldiers rescue villagers from the floodwaters. More than 1,800 people were killed in the disaster.

Beating back the sea

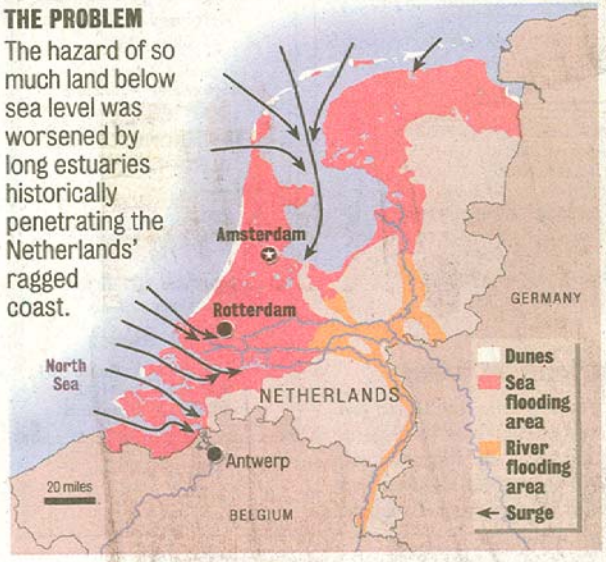
HOW THE DUTCH FIGHT TO SAVE THEIR LOW-LYING LAND

BATTLE AGAINST THE SEA

Much of the Netherlands is below sea level, in some places 20 feet below, a vast outwash where three major European rivers wind their way to an often violent North Sea. Not surprisingly, water management is a national religion, and today the Netherlands is the global gold standard in flood control.

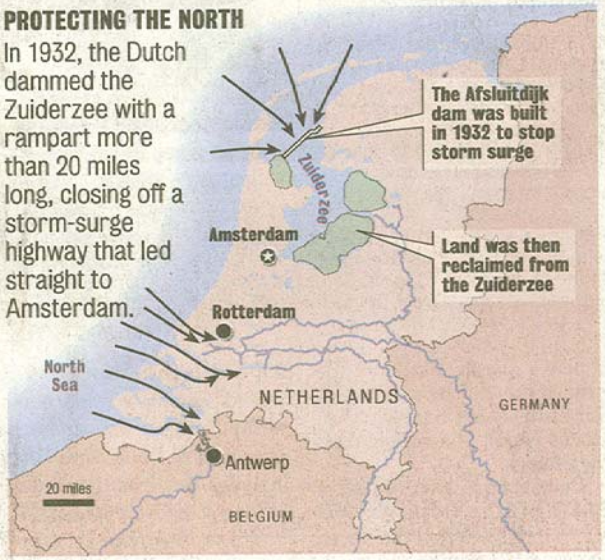
THE PROBLEM

The hazard of so much land below sea level was worsened by long estuaries historically penetrating the Netherlands' ragged coast.



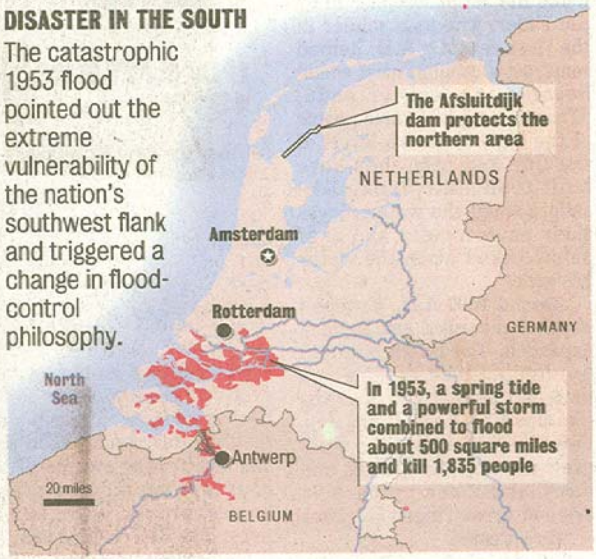
PROTECTING THE NORTH

In 1932, the Dutch dammed the Zuiderzee with a rampart more than 20 miles long, closing off a storm-surge highway that led straight to Amsterdam.



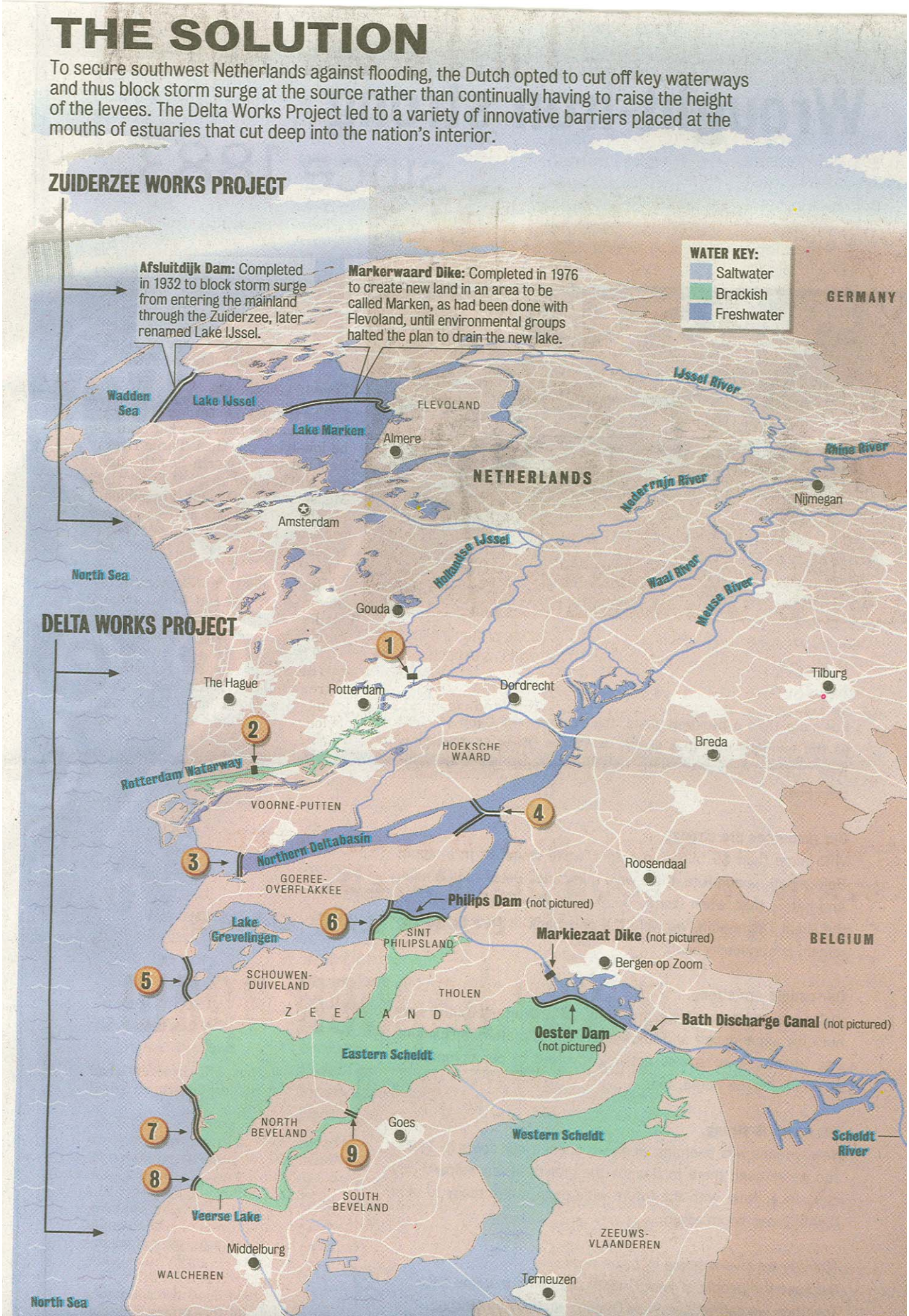
DISASTER IN THE SOUTH

The catastrophic 1953 flood pointed out the extreme vulnerability of the nation's southwest flank and triggered a change in flood-control philosophy.



THE SOLUTION

To secure southwest Netherlands against flooding, the Dutch opted to cut off key waterways and thus block storm surge at the source rather than continually having to raise the height of the levees. The Delta Works Project led to a variety of innovative barriers placed at the mouths of estuaries that cut deep into the nation's interior.



1 HOLLANDSE IJSSEL STORM SURGE BARRIER

Storm surge barrier protects the lowest region of the Netherlands. Two enormous doors span the 260-foot wide structure, suspended between two towers. When water levels rise too high, the doors are lowered and dam the river.

Completed: 1958

2 MAESLANT STORM SURGE BARRIER

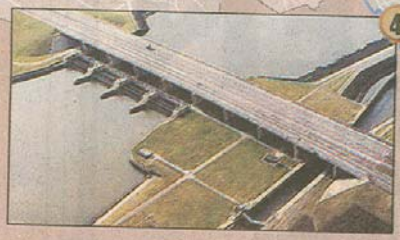
Storm surge barrier protects Rotterdam. Huge gates — each nearly as wide as three football fields — sink into the shipping channel after they swing shut. Generally, though, they stay open. The structure is expected to be used once or twice a decade.

Completed: 1997

3 HARINGVLIET DAM

Open dam prevents flooding while also allowing drainage between two key rivers and the North Sea. When levels near Rotterdam get too high, drainage sluices remove excess water. The structure includes tunnels to allow fish to swim to and from the North Sea, even when the dam is closed.

Completed: 1970



4 VOLKERAK DAM

Dam built primarily to aid in the creation of other dams. It prevents too much freshwater from flowing into the brackish waters of the Zeeland and includes a lock to facilitate shipping between Antwerp, Belgium, and Rotterdam.

Completed: 1969

5 BROUWERS DAM

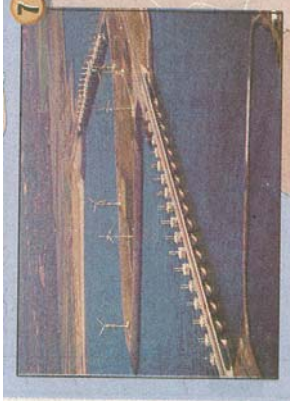
To create the dam, sandbars were enlarged, giant caissons were sunk then filled with sand, plus more than 660,000 tons of enormous concrete blocks were plunged into the sea. The dam, however, blocked tidal flow, destroying the area's character. In 1978, a sluice was built into the dam to restore salinity levels.

Completed: 1971

6 GREVELINGEN DAM

Nearly 4-mile dam created across sandbars to facilitate construction of other dams in the area and to prevent water from manmade lakes created by the other dams from flowing back toward the sea.

Completed: 1965



7 EASTERN SCHELDT STORM SURGE BARRIER

Originally envisioned as a dam, plans were completely revised, partly because of unintended environmental changes wrought by the Brouwers project. The dam would have destroyed oyster farming and decimated the fishing industry. The partially built structure was modified into a barrier with a series of giant doors that slide shut during a storm.

Completed: 1986

8 VEERSE GAT DAM

9 ZANDKREEK DAM

Dams designed to connect islands and block key flood pathways. A brackish lake, the Veerse Meer, between two islands was created upon completion of the dams.

Veerse Gat completed: 1961
Zandkreek completed: 1960

Staff graphic by Dan Swenson and Emmett Mayer III

STAFF PHOTOS BY MICHAEL DEMOCKER WITH CONTRIBUTIONS BY DUTCH MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT

Sources: "Water in the Netherlands," "The Delta Project," Deltawerken, staff research

PART 2 OF 3

Beating back the sea

HOW THE DUTCH FIGHT TO SAVE THEIR LOW-LYING LAND

Raising levees became a losing game for the Dutch. So with a grand vision, they revolutionized flood control.

Bigger. Better. Bolder.

Louisiana must think ahead, they say, not seek a quick fix.

Entering the Rotterdam Waterway canal from the North Sea, a ship passes through the Maeslant storm surge barrier. The two gates swing shut and sink during storms to protect more than 1 million people from rising seas.

HOEK VAN HOLLAND, NETHERLANDS

Like two enormous butterfly wings, massive yet delicate, the 700-foot-wide gates of the Maeslant storm surge barrier sit on either side of the New Waterway, a shipping channel that runs from the North Sea into the heart of Rotterdam, Netherlands.

Most of the time, sitting is all they do.

But Rotterdam, the world's busiest port, and the densely populated area around it are the lowest region of a low country, 22 feet below sea level at its nadir. It would be wiped off the map if allowed to flood. So when a major storm surge threatens the Dutch coast, something that has happened just once since the barrier was completed in 1997, Maeslant's automated system responds.

The barrier's computer system monitors weather conditions and regional water levels, and an approaching storm surge triggers the gates to close. Motors kick on and gears spin, sealing off the waterway. The gates rotate on 680-ton ball joints made of steel, 35 feet in diameter – the largest in the world. When they meet in the middle of the channel, the 70-foot-high barriers fill with water and sink to the bottom. The surge is blocked.

"You need no human intervention. We wanted to reduce the risk of human error, so it's completely computer operated," said Thijs Damsma, an engineering student and guide at the barrier.

See **NETHERLANDS,** *A-6*

RUIN & RECOVERY

An occasional series on how others responded to disaster

Stories by John McQuaid
Staff writer

Photos by Michael DeMocker
Staff photographer

"The computer system is four times redundant."

A model of success

New Orleans is clamoring for a bigger, stronger levee system that will prevent a repeat of the flooding caused by Hurricane Katrina. But Dutch engineers say that's not enough: It will also have to be a smarter levee system.

The Netherlands employs the latest in safety principles and digital technology to design for the long haul. New Orleans levees were outdated long before their target date for completion. The Maeslant barrier is designed to last at least a century. Another structure, the Eastern Scheldt barrier, is meant to last twice as long.

The Dutch say thinking ahead is the only option in designing flood defenses: Plan obsessively. Look at the big picture. If things change, adjust. Those are clichés, perhaps, but they're based on hard-won experience from 1,000 years of fighting floods.

With New Orleans' short- and long-term security and rebuilding efforts hanging in the balance, the political pressure is intense to build Category 5 hurricane protection, and build it quickly. But Dutch engineers also caution it would be a mistake to rush forward and build without a clear strategy.

"The first question is, what do you want to protect, people or the marshes? Define your problem – analyze the system that way. Which is the system? The sea, the river, the lake, the weather? Which problem do you want to solve?" said Tlaje de Haan, an engineer with the Netherlands' water and public works department who helped design the Eastern Scheldt barrier. "Don't go in a hurry to build something. This is an engineer's wish – to go somewhere and just start building."

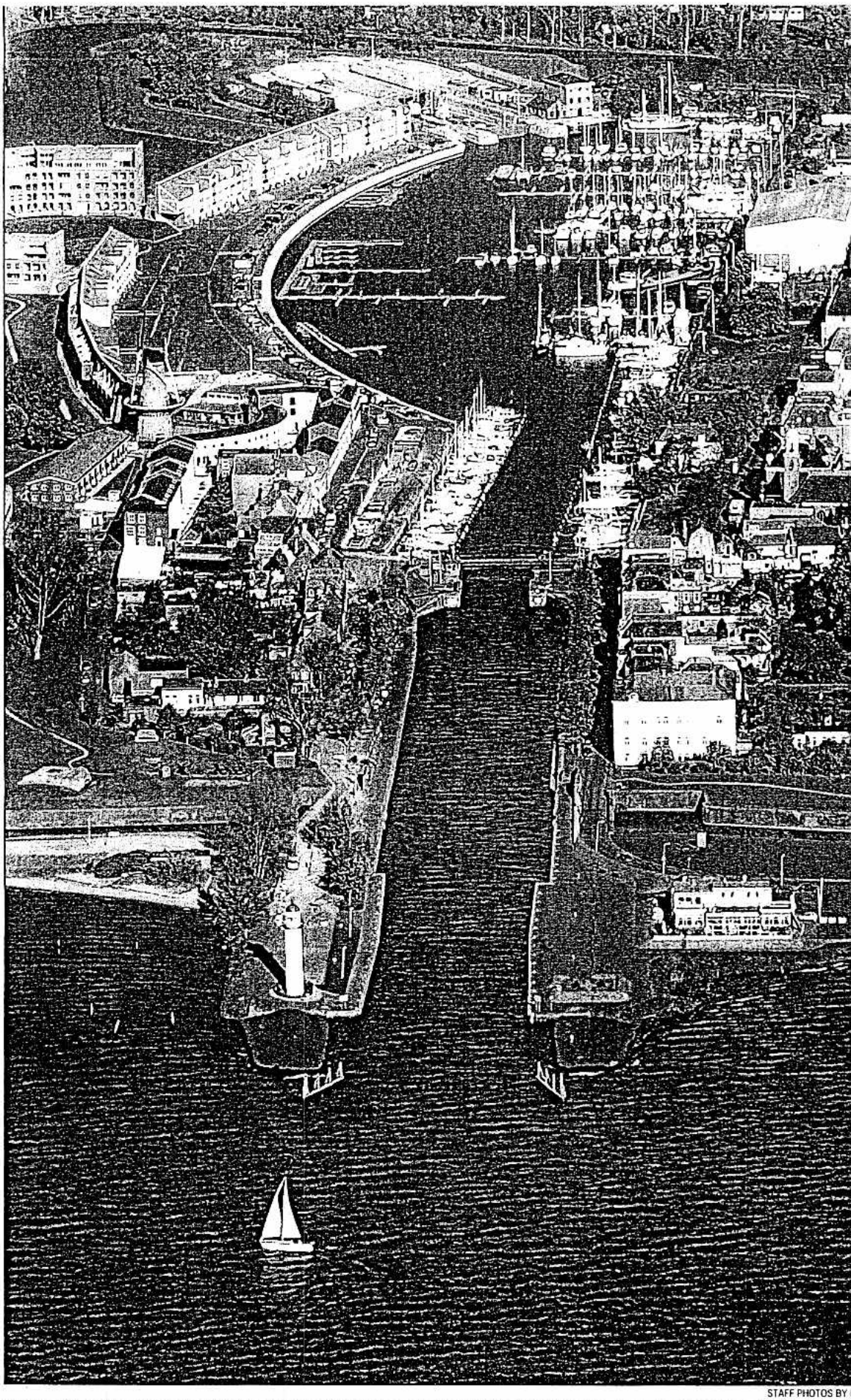
Chronic problem

The Dutch created space for settlements and farming by reclaiming land from the water. But reclaimed land sinks, and water always seeks the lowest point. It seeps in through the soil, pours from the sky and sweeps across the landscape as it floods. Through necessity, people devised dozens of methods to expel it, repel it and generally to control it.

Those efforts haven't always succeeded. Today's flood defenses are the product of repeated failures that forced people to start over and innovate.

Before the country's devastating 1953 flood, for example, studies and commissions had identified serious weaknesses in the dike system and proposed solutions – mainly higher, stronger dikes. But the country was still recovering from the Nazi occupation, not to mention the actions of the Allies, who bombed some dikes to flood the Germans out. The recommendations were ignored.

The high price of that missed opportunity drove the creation of the Delta Works, a



STAFF PHOTOS BY

Many seaside villages, such as this one on the outskirts of Rotterdam, are protected by the Delta Works flood control project. After a 1953 North Sea st killed more than 1,800 people, the Netherlands invested billions of dollars in a complex system of dams, storm surge barriers and gates.

network of huge barriers, gates and dams that protects the country's vulnerable southwestern region from storm surges. "We knew the dikes were weak. But we did not always see the problem, and people remember this," said Marion Smit, the top water policy official at the Ministry of Transport, Public Works and Water Management.

The cycle has created a countryside layered with flood-control methods from the present and centuries past – some of the latter still functioning. Canals dating to the Middle Ages run next to Renaissance-era windmills. Pumping stations set up during the Industrial Revolution stand a stone's throw from 20th-century dams and floodgates.

Many of these technologies revolutionized flood protection when they debuted. The development of the windmill for drainage purposes in the 15th century allowed inhabitants to expand agriculture and settlement areas, creating the modern landscape of polders, canals and dikes. The land is tiered – some areas are lower than others, and the water table must be maintained at different depths. This was done by windmill-powered scoop wheels moving water from one level to the next.

"You had a scoop wheel that could raise the water only 5 to 6 feet up. If you want to reach sea level, you'd need three of them. Depending on how steep the steps, in some cases they would be close together, in others 10 kilometers (about six miles) apart," said Jurjen Battjes, a professor emeritus of engineering at the Technical University of Delft. Battjes graduated from a government-sponsored program that apprenticed him for a time to a windmill operator.

Big thinking

Windmills and pumping stations are there to move water out. The Dutch also developed effective barriers to keep it from getting in. The oldest are dikes, earthen structures similar to levees. Traditional dikes were built by laying clay soils over rocks, then lining the dike with stones or tiles. On the dry side, builders would lay down a thick woven mat of willow twigs as scour protection. Should the dike be topped, the mat would prevent the water from eroding the base of the structure, something that could lead to a breach. Some New Orleans floodwalls breached because they had no scour protection, and Army Corps of Engineers officials said they had no mandate to build it. But even a low-tech willow mat might have made a difference.

But 20th-century flood threats in the Netherlands proved significantly worse than in the past, and engineers moved in bold new directions. The Delta Works demanded a reimagining of the nation's entire flood control system. Small was out, big was in. When big dams caused environmental problems, the Dutch responded by building more flexible structures that would allow water to flow in and out. U.S. engineers may face similar challenges if they build large gates at the passes into Lake Pontchartrain as part of Category 5 protection.

One model will be the huge Eastern Scheldt storm surge barrier, which cost $7.8 billion – more than corps estimates for the entire cost of Category 5 upgrades in and around New Orleans. The Oosterschelderkering, as it's known in Dutch, snakes in three segments across a five-mile opening on the North Sea, its distinctive white pillars visible from miles away. The barrier's 62 steel gates are usually open, allowing tidal flow in and out.

Massive undertaking

Nothing like the barrier had ever been built before. "It was a process of trial and error. There was a first design, and the people said this would not work. So there was a second, a third, a fourth," de Haan said. "For a hydraulic engineer, this was like putting a man on the moon."

Design is only half the battle. There are no prefabricated parts for such a structure, no established guidelines for making or assembling them. Building 65 massive concrete piers, the barrier's main structural element, forced engineers to invent their way around one obstacle after the next.

Each pier weighs 20,000 tons, stands between 100 and 125 feet high and took 18 months to construct. Workers created an open-air pier factory with dozens of monoliths under construction at a time. When one set of piers was complete, the area was flooded, and a special, U-shaped ship lifted each pier and moved it into place, where it had to be positioned to within a few centimeters.

The piers rest on huge mattresses designed to absorb changes in water flows that would otherwise erode the soil underneath. The mattresses, steel mesh "cloth" containing sand and gravel, are more than 600 feet long and 140 feet wide. They were put on a giant roller that unspooled them onto the bottom of the channel.

As the Netherlands has grown more densely populated, flood defense has had to adapt to changing social and economic circumstances. When officials were studying how to protect Rotterdam after the 1953 flood, for example, they first proposed upgrading the city's dikes. Residents protested because the new dikes would be much larger, impinging on neighborhoods. Historic buildings would have to be condemned. And as time wore on, the cost of the dike project rose so high it was abandoned.

The solution was the Maeslant barrier, a single $700 million structure located near the mouth of the waterway that protects everything behind it – and has no effect on ship traffic. Officials held a contest to choose the design. One entry was a pair of hollow gates placed at the bottom of the channel that would rise when filled with air. The butterfly wing project won out.

With the Delta Works complete, officials and engineers are also taking a step back and re-examining the basic design principles of their flood defenses.

Anticipating failures

Whether they are storm surge barriers, dikes or levees, flood control structures are all designed on one principle: They must repel a calculated flood height.

But engineers studying that basic standard wondered if it failed to capture how flood control really works – and their conclusions apply directly to New Orleans, where some levees failed without being topped, apparently due to design or construction flaws.

Levees are more than just objects of earth, rock, concrete and steel. Their functioning also depends on a range of other factors: construction standards and quirks, maintenance, emergency plans – and human beings. If all those elements were considered when risks were analyzed, engineers say, the results would be alarming.

"You consider all kinds of ways a thing might not function," said Battjes, who sits on a government committee that recommends the new philosophy be turned into policy. "If you have a movable gate, for example, how might it fail? The foundation might fail, and the thing might collapse. The gate may not function. The guy may not be there to operate it. All of these things have certain probabilities."

Balancing those risks against what the system protects is a much smarter way of doing things, Battjes said. U.S. engineers appear to be way behind in this regard. The safety standards for levees are too low, he said. They date back to the early 20th century, before levees protected big cities, millions of lives and billions of dollars of infrastructure.

"The more you invest, the less likelihood of danger. You can overinvest and underinvest. In New Orleans, it looks like they underinvested. They took a lot of chances and had some heavy damage," Battjes said. "If you want to have people safeguarded, you have to make sure, instead of looking just at the crest of the dike, that the whole system is looked at – with all the structures included and balanced with what's inside."

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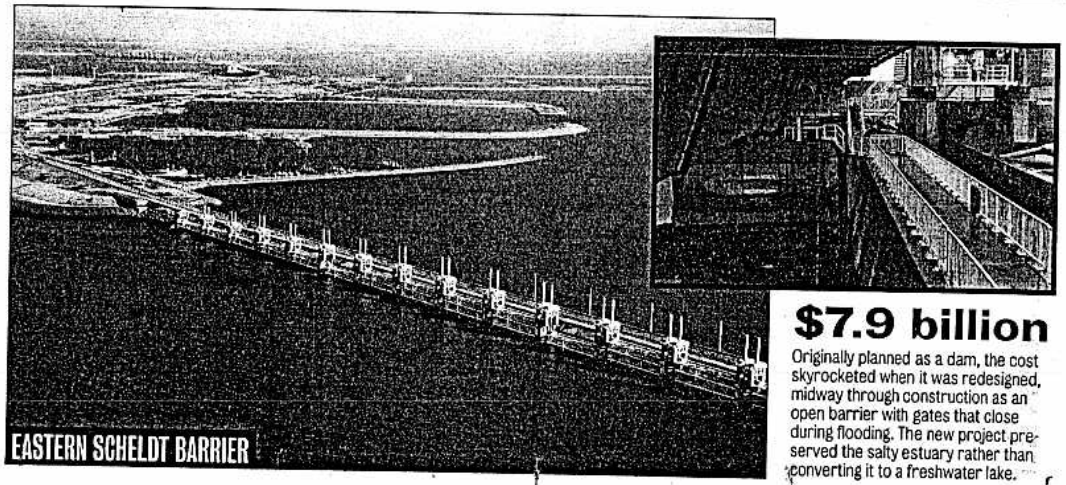
John McQuaid can be reached at (202) 383-7889 or john.mcquaid@newhouse.com.

The price tag

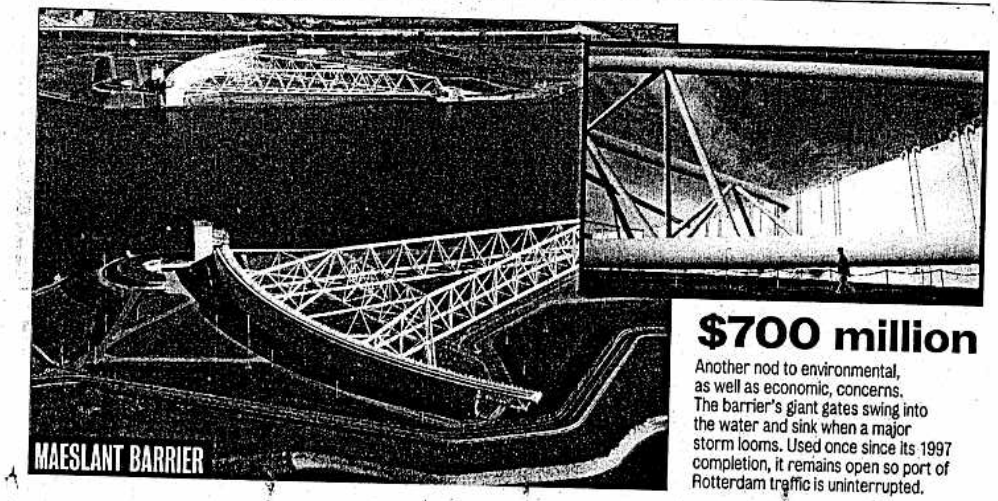
The Delta Works envisioned in 1955 was to be finished within 25 years. Anticipated cost? $1 billion in today's dollars. Forty years later, it was finished at a cost of $14.7 billion.



EASTERN SCHELDT BARRIER

$7.9 billion

Originally planned as a dam, the cost skyrocketed when it was redesigned, midway through construction as an open barrier with gates that close during flooding. The new project preserved the salty estuary rather than converting it to a freshwater lake.



MAESLANT BARRIER

$700 million

Another nod to environmental, as well as economic, concerns. The barrier's giant gates swing into the water and sink when a major storm looms. Used once since its 1997 completion, it remains open so port of Rotterdam traffic is uninterrupted.

A plan to prevent a sharp bend in the river from turning into a flooding nightmare would wipe out dozens of riverside homes.

Flood of protest

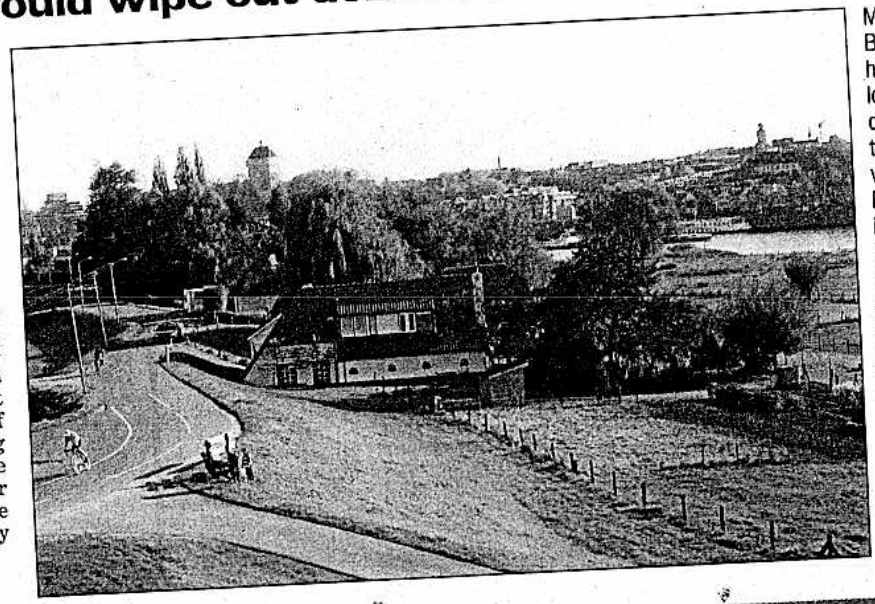
By John McQuaid
Staff writer

LENT, NETHERLANDS — Maarten Broekman's early 19th century house stands on a batture at a sharp bend in the Waal River. An earthen dike towers 20 feet behind the house. In front, a sun-dappled, grassy expanse stretches 300 yards to the river's edge, giving Broekman and his family a sweeping view of the city of Nijmegen on the other side.

When the river, a tributary of the Rhine, rises in the winter, that expanse can flood. Sometimes, water laps onto Broekman's patio and he pumps it dry. During the last major flood — in 1995 before he moved in — 3 feet of water came into the house.

Now the Dutch government wants his house out of the way. Concerned with rising water levels in the river, officials want to buy up homes in the area and dig an emergency channel straight through Broekman's property. Part of a coordinated plan to prevent flooding along the length of the Waal River, the channel would act as a holding basin for storm waters, in somewhat the same way that the Bonnet Carre Spillway

See **RIVER,** *A-13*



Maarten Broekman's house sits below the earthe dike that protects the area when the Waal River overflow its banks. Broekman anc his neighbors are asking the government tc consider a na rower flood basin that would preser their homes and still provide flood pr tection.

Works envi-

can be seen

Residents weigh in on projects

RIVER, *from A-11*

into Lake Pontchartrain provides a safety valve when the Mississippi River is at flood level.

But Broekman isn't selling, at least not yet. He helped organize a neighborhood group to oppose the plan. They devised an alternative: Dig a narrower basin. That would preserve the homes and still provide flood protection — though it would last for about 50 years, just half the century-long lifespan projected for the government's solution.

Though most of the Netherlands is protected from river and ocean floods by a carefully maintained system of dikes, dunes and storm-surge barriers, officials say it's still not safe enough because of melting snow, rising seas and sinking land. Dutch law requires that certain safety levels be maintained. Even now, officials warn, some areas have dropped out of compliance.

"Our system has changed," said Marion Smit, the top water-policy official at the Ministry of Transport, Public Works and Water Management. "We have global climate change, the possibility of higher storm waves on the coast. So we are taking another look. Not every area of the Netherlands is as safe as defined by the law."

Shoring up defenses

The Dutch have embarked on an effort to gauge their flood defenses and figure out which should be strengthened to account for the changes.

Part scientific guesswork, part engineering, part politics, it is a difficult process but one that officials say is necessary to avert a disaster 50 or 100 years — or less — down the line.

It's the approach American officials will have to adopt if they want to keep New Orleans safe behind a restored storm defense network. Building a Category 5 hurricane levee system for 2005 conditions won't do much good if by 2055 the Gulf of Mexico has risen by a foot and hurricanes have gotten stronger and more frequent, as some predictions suggest.

The Dutch water ministry is spending $3.5 billion to upgrade river defenses, a project called the Delta Plan for the Major Rivers. The effort came in response to major floods in 1993 and 1995. The February 1995 flood overflowed all three of the Netherlands' major rivers. No one died, but 250,000 people were evacuated, and property damage was heavy.

Rather than simply raise dikes all along the rivers, the government has turned to a couple of more controversial methods. During a future inundation, some rural flood plains will be deliberately flooded to prevent disaster downstream. In other places, rivers are being widened and compartments or channels dredged to temporarily divert water. The ministry has also launched a public awareness campaign called "Living with Water" to sell a sometimes skeptical public on these concepts.

"We know the possibility of failure in low-lying areas is rising. The bottom is going down. The possibility of evacuation is remote," Smit said. "Which is why it's very important to have more space for water: to look at natural processes, to work not against nature but with nature."

Lent and Nijmegen flooded in 1995, and the narrow, 90-degree bend in the river is especially problematic because it is a bottleneck that can slow down the flow, forcing the river level higher upstream. If more space could be created at the bend, then that problem would go away — at least for a while.

Early scenarios included a diversion across the back side of town, something that would have turned Lent into an island during a major river flood. But the idea was scaled back after residents complained. The current proposal would still claim 55 houses on both sides of the river dike — a pleasant neighborhood of homes and winding streets between two bridges. At least five of the homes have historic status.

The Dutch system depends heavily on the involvement of community organizations, a process called the polder system, named for the reclaimed land surrounded by dikes where most of the people live.

"We consult them every time. It's impossible to make a plan without consulting those organizations. We try to get a commitment early on," said Arnold van der Wees, an environmental engineer at the ministry.

"That's the Dutch polder system: Whether you are rich or poor, we all live in the same polder — below sea level."

Broekman and some neighbors formed a group called, roughly, "People Suffering from the Lent Dike Relocation." It aims, if possible, to forge a compromise. Members have met twice with the Cabinet minister overseeing flood defenses and with Smit as well. While the government's buyout offer is for current market value, they say they don't want to move.

"The houses, that's not the problem. These locations are very rare in Holland anymore," said Jos Verstappen, a neighbor who belongs to the group, gesturing at the green expanse in Broekman's front yard. "Holland is densely populated. This space is unique."

They partnered with a retired engineer to devise their alternative, which would preserve the neighborhood at the price of longer-term protection — but, they say, for about 60 percent of the cost of the government plan.

Planning ahead

The debate has an air of abstraction because it is based on scientific estimates of future water flows, which could prove to be wrong. The government's target is to guard against high water flow levels that it projects could be routine in 100 years — about 18,000 cubic meters per second. The local group is willing to settle for protection against flows above 17,000 cubic meters per second. The river flow per second has not yet topped 12,500 cubic meters.

"Our plan is good for 50 years. The government is looking at a plan for 100 years. If in the future it's necessary to do this, then you can go ahead and do things here then," Verstappen said.

Such debates might prove problematic in the U.S. political system, where some segments of the public and some elected officials are skeptical about the reality of global warming. But it is especially important for Louisiana, which already is suffering more than other areas from rising seas and more frequent or intense storms — whatever their cause. In that respect, engineering the Louisiana coast will be more difficult than the Dutch coast because hurricanes are a more frequent and powerful threat than North Sea storm surges.

The ministry is supposed to decide this month between the 50- and 100-year plans. Residents don't know which way it will go, but they are prepared. "If they choose their plan, we will protest," Verstappen said. "There will be a juridical process. It will take years."

WATER WAYS

A bend in the Waal River separates the cities of Nijmegen and Lent but also poses a major flood danger. The government wants to buy out 55 homes and build a holding channel, while residents have a different plan to save their homes.

Source: Staff research

STAFF GRAPHIC BY EMMETT MAYER

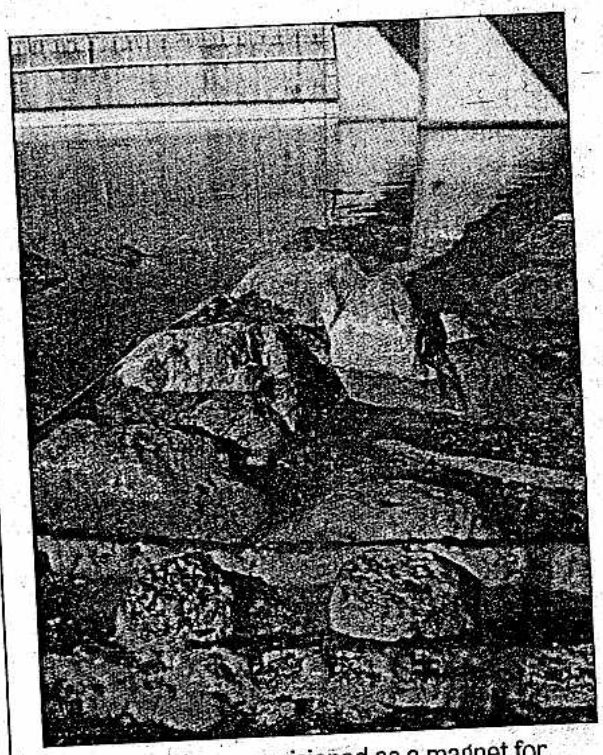
PART 3 OF 3

Beating back the sea

HOW THE DUTCH FIGHT TO SAVE THEIR LOW-LYING LAND

Give & take

The Dutch found out the hard way: Flood control can create as many problems as it solves.



Lake Volkerak was envisioned as a magnet for recreation and tourism after other projects in the region damaged fisheries. But the plan backfired. Because of pollution and runoff flowing downstream from Germany and France, toxic algae have taken hold, and today the lake is a fetid mess.

LAKE VOLKERAK, NETHERLANDS

The Grevelingen estuary was a mortal threat, so it had to go. During the 1953 Dutch flood disaster, the estuary, where the Meuse and Rhine rivers flow into the North Sea, was a conduit for a storm surge that flowed inland and killed hundreds of people.

So the Dutch government dammed Grevelingen in 1971 as part of its Delta Works flood protection plan. It built a dam to block off the North Sea and then still more dams that divided the estuary into compartments to make the waterway more manageable. But that solution created a different kind of disaster.

Grevelingen's tidal fluxes and sand flats had made it a perfect home for sea life, including shellfish. "All the mussels were dead within 14 days after the area was dammed," said Wim Schott van Sluis, 69, who had fished in the area.

Officials wanted to make up for lost fisheries by turning the lakes into magnets for recreation and tourism, but that plan also backfired. Lake Volkerak, a freshwater compartment, is regularly

See **NETHERLANDS,** *A-11*

RUIN & RECOVERY

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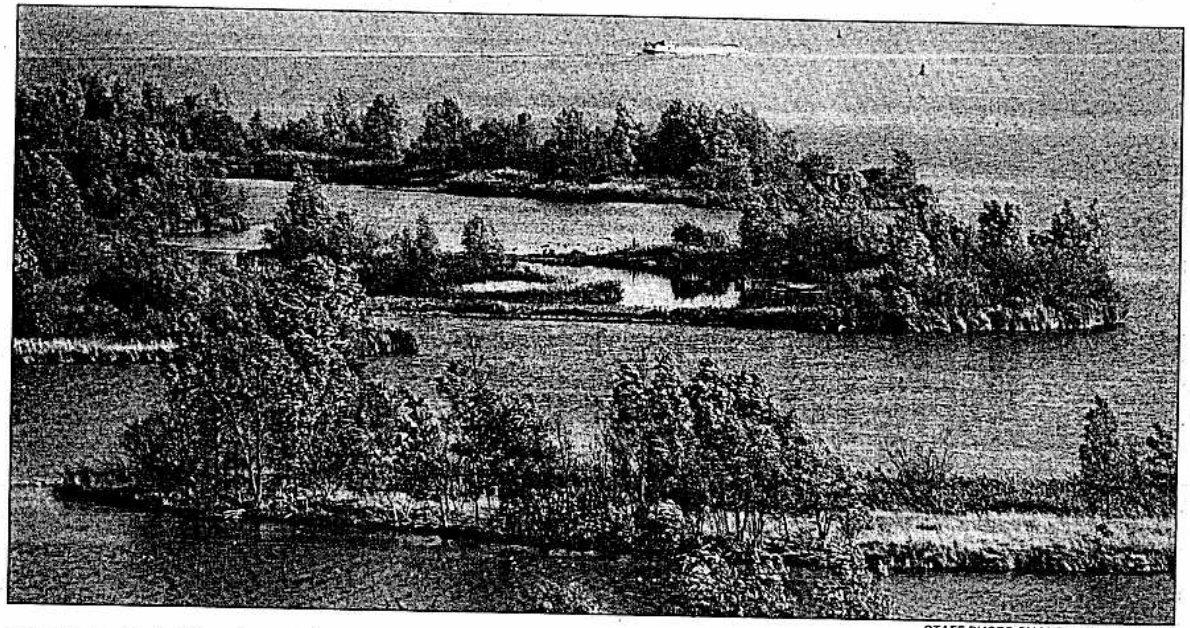
INSIDE

▶ **Some Dutch are**

Holland's fixes are often hit or miss

STAFF MAP



STAFF PHOTO BY MICHAEL DeMOCKER

The islands of Lake Volkerak may look picture-postcard perfect, but the lake is regularly overloaded with nutrients flowing downstream from Germany and France, creating a kind of dead zone.

NETHERLANDS, *from A-11*

mental movement, and a leftward shift in Dutch government combined in 1974 to end the dams-only policy. The various stakeholders compromised on a more flexible approach: the gated barrier.

Saeijs joined the Delta Works and oversaw the program's shift to ecological management. "We were jumping on a fast-moving train," the biologist said. "The Grevelingen estuary was lost — everything was so rotten, so poisoned, that we had no desire to work there. In the second area, the north of the Oosterschelde (Eastern Scheldt), it still had tidal flow."

Saejis recommended that Grevelingen be turned into a saltwater lake. A sluice was built into its North Sea dam, called the Brouwersdam, to allow sea water to flow in and out. Today, the lake is considered a relative success story; fish and some life have returned, and the clear water draws divers. But better environmental management didn't put a stop to the challenges. If anything, they were only beginning. Soon each of more than a half-dozen bodies of water created by the change in policy — estuaries, freshwater and brackish lakes — was asserting its own character and management demands.

The Western Scheldt estuary was left open, and dikes were built to protect the adjacent land, to allow easy shipping to Antwerp, Belgium. The Eastern Scheldt barrier had gates that were impassable to ships. At Grevelingen, there was a dam with a sluiceway. At Haringvliet, sluicegates let river water flow out but were not supposed to let ocean water flow in. And more dams were built to limit tidal flows further inland.

Foreign species invade

Behind the dams, pollution is a problem. More than 5 billion cubic feet of polluted sludge from the Rhine and Meuse has settled in the Haringvliet lake — the only saving grace being that it didn't end up in the North Sea.

Marsh areas that depended on the right balance of saltwater and fresh water are slowly dying as fresh water takes over. Where shrimp, mussels and oysters once thrived, invasive freshwater zebra mussels, the same species that plagues U.S. waterways, have taken up residence.

Things are better on the Eastern Scheldt. But while building gates might have saved the estuary, it also played havoc with water flows and topography — and that in turn has hurt the area's ecology. The barrier reduced tidal flows by about 30 percent. That cut down the regular silting of its deep channels, which in turn sped up erosion of nearby sandbars. Migrating birds depend on the sandbars for shellfish and other food. The less sand is exposed during a low tide, the less food there is and the fewer birds the area can support. Now birds such as stilt and the red breasted goose are slowly disappearing.

"We anticipate the sandbanks will disappear. We've got salt marshes — they will all disappear," van der Wees said. "This is a migration route for birds to Siberia. This is a main route. They all eat on the sandbanks and tidal flats. Normally in an estuary there are two processes: sedimentation and erosion, and they are more or less in balance. But with the tidal (processes disrupted), what we get is erosion."

The mussel fishery continues, Schott van Sluis said, just in a different place. But it's threatened by another invasive species, a Japanese oyster that has spread to all corners of the estuary. When the tide recedes, clumps of oysters can be seen stretching for miles along the estuary's mud flats. They are displacing mussel and cockle beds that are depended on by fishers. Though they are harvested, demand for the oysters is limited so fishers can't just switch, and because birds can't eat them, the oysters' expansion is depressing the bird population.

Scientists at the Netherlands Department of Public Works and Water Management, roughly equivalent to the Army Corps of Engineers, have worked hard to address these problems. But often their solutions have fallen short.

Lake Volkerak was dammed in 1987 to eliminate tidal changes along a shipping link between the Scheldt and the Rhine. Authorities tried to create ecological stability by introducing pike into the now-fresh water lake to occupy the top spot in the food chain and eat other fish that were multiplying out of control.

But the lake proved a poor habitat for pike, and they never established themselves. Meanwhile, biologists hoped that water fleas in the lake would eat algae and keep it under control. But that also failed to pan out. Today, the lake is a fetid mess, and biologists are still searching for solutions. Water administrators propose opening up Lake Volkerak next year to allow some

See **NETHERLANDS,** *A-13*

overloaded with nutrients flowing downstream from Germany and France, creating a kind of dead zone. "Every summer it's blue-green. It stinks. You can't swim there anymore — it's toxic algae," said Arnold van der Wees, an environmental engineer for the Dutch Department of Public Works and Water Management.

As the Netherlands has used ever-more ambitious, large-scale methods to repel floods, people have come to realize that safety and security have a hidden price tag: The bigger the fix, the bigger the unintended consequences.

"When you interfere with natural processes, you have to keep interfering," van der Wees said. "If we knew then what we know now, we probably would have found other solutions to create safety."

The Dutch experience is a cautionary tale for south Louisiana, where engineers might have to intrude on the delicate marshlands surrounding New Orleans as never before, building new floodgates and levees to protect the region against a Category 5 hurricane.

Hurricane protection and marsh restoration projects will have to be knitted together into a single system with divergent goals. Storm surge protection requires walls of one kind or another. But estuaries and marshes are living systems. Wall them off and they might die. Putting holes in the walls can help by letting water flow in and out. But no one really knows how — or if — these ambitious aims can be balanced.

Dutch scientists say it's imperative to anticipate long-term problems such as marsh erosion.

"You can delay it to a certain extent, but some of the processes cannot be stopped," van der Wees said. "It will never be the same here as it was before the 1953 flood. Interfering with natural processes and natural systems is always a bad thing. Mother Nature is the best engineer.

"My advice would be not to interfere too much, but allow natural processes to continue."

Paying more attention

Though the Delta Works and other elements of the Dutch flood defenses are complete, the environment in which they sit is still a work in progress. Between 1900 and 2000, the total estuary area in the Netherlands, including marshlands, shrank by more than half, from 3,340 to 1,520 square miles. The Netherlands has repeatedly built dams and other barriers, then been forced to go back and clean up the environmental messes they have created.

Even the environmentally friendly Eastern Scheldt storm surge barrier, built with gates rather than dams to preserve the estuary behind it, has caused so many problems — erosion of ecologically important sandbars paramount among them — that some environmental groups are pushing for it to be dismantled.

Chastened Dutch officials and engineers are now more cautious about the negative impacts of flood protection. Those include not only endangered bivalves and birds but fisheries, tourism and the quality of life for the region's residents, many of whom belong to community groups involved in the government's decision-making process. It's called the polder system, polders being the reclaimed and diked areas most people live in.

"Shortly after 1953, there was one goal: We need to block this off as soon as possible. Then the environmental issues became much more important," said Marion Smit, the top water policy official for the Ministry of Transport, Public Works and Water Management. "If you had made a cost-benefit analysis then (that included the environment), I don't know that they could have done what they did."

Dams and dikes in the Netherlands traditionally served two purposes: land reclamation and flood protection. Those were the aims of the Zuiderzee Works, the giant project in the northwest part of the country that, in 1932, dammed the Zuiderzee, an inland sea, and created a giant freshwater lake, and in it, huge polders for farms and living space.

The aim of the Delta Works Plan, begun in the early 1960s, was similar: block storm surges and spur development. No huge polders would be created, but planners wanted to give the mostly rural area an economic boost by connecting its many islands with dams and bridges, said Kees van der Maas, retired editor of the Provinciale Zeeuwse Courant newspaper, who covered the Delta Works Plan during its formative years.

Another invasive species, a Japanese oyster has spread to all corners of the estuary. When the tide recedes, clumps of oysters can be seen stretching for miles along the estuary's mud flats. They are displacing mussel and cockle beds that are depended on by fishers.

Authorities had little environmental knowledge. "Fresh water was seen as only something for human use, and saltwater was pollution," said Henk Saeijs, a biologist and former chief of the Delta Works environmental department.

The delta has four major estuaries, each with a complex ecology, each with a long maritime history. Damming them was a radical environmental and social change — too radical, as it turned out.

By the late 1960s, the dams were losing their political support. Incensed at the certain destruction of oyster and mussel beds, for example, fishers in the Eastern Scheldt estuary started protesting the dam project there, forming an unlikely alliance with environmental groups.

Schott van Sluis, whose family has fished the area since the 1600s and who rescued hundreds of people by rowboat in the 1953 flood, had not been involved in politics before. Yet at one point he joined a protest flotilla that surrounded a boat carrying a provincial administrator.

"Though fishermen had done a lot in the disaster, saving people's lives, politicians did not remember what happened," he said. "They did not want to listen to the fishermen."

The fierce opposition of fishers, the growing influence of the environ-

See NETHERLANDS, A-19

Dutch reverse course, give up some land

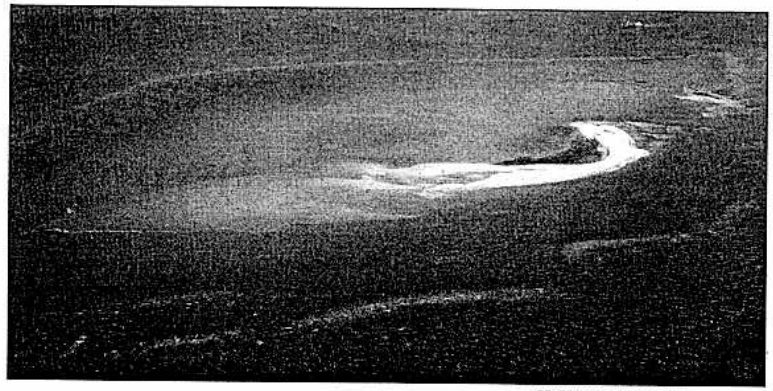
NETHERLANDS, *from A-12*

flow of saltwater in hopes of reducing the toxic algae problem.

In some spots, government scientists are trying to create new marshland habitats to replace the disappearing ones. They stop pumping out pastureland, and saltwater gradually seeps in and reclaims it. At one experimental site outside the town of Zeirikzee, the shift from pasture to marsh is embodied in the animals that dwell there. Cows stand alongside an area of grass, mud and water, and geese land and settle in the puddles.

Scientists are hoping to try this approach on a larger scale. The new philosophy calls for reversing the whole trend of Dutch history: giving up some reclaimed land and letting water reclaim it. The general idea is that if water has more space, it is less likely to flood inhabited areas. That could mean removing dikes or dams or reconfiguring them. It could mean widening rivers that are likely to flood. It's another idea that could reverberate in New Orleans, where suggestions include abandoning some vulnerable areas rather than risking a future flood.

"Not only land reclamation is important, but to give land back to the sea is important," Saejis said. "If you give land back to the water, water will not come as high as when you reclaim it."



STAFF PHOTOS BY MICHAEL DeMOCKER

A sandbar, ABOVE, rises out of the waters behind the storm surge barrier in the Eastern Scheldt. Flood control projects have led to the erosion of such sandbars, which attract migrating birds, and have earned the concerns of environmentalists. Geese and other migratory birds, LEFT, could become unintended casualties of the Delta Works projects, which have reduced tidal flow and endangered the marshland and sandbars that the birds rely upon to search for food.

From the Netherlands ...

LESSONS LEARNED

Holland's battle with high water offers insight for another low-lying land, Louisiana.

SHORTEN THE LINE OF DEFENSE. By building dams and floodgates at key junctures, the Netherlands has effectively reduced its coastline, concentrating maximum resources at the weakest points and eliminating the worry that inland dikes are subject to catastrophic failure.

MAINTAIN SAFETY STANDARDS OVER TIME. As in south Louisiana, the Dutch landscape is sinking while sea and river levels are rising. The government closely monitors those changes and continually upgrades its flood defenses to keep pace with them.

DESIGN AND BUILD WITH THE WHOLE SYSTEM IN MIND. As New Orleans learned the hard way, levee height is just part of a puzzle that must be analyzed to see how the system will work as a unit, including its various structural elements, the roles of different agencies and possible sources of human error.

ESTABLISH CLEAR SAFETY STANDARDS. The Netherlands' legally mandated risk levels for dikes, dams, dunes and barriers set both a high engineering standard and reassure citizens that the country is safe.

PRESERVE THE NATURAL ENVIRONMENT. Building big structures in sensitive coastal environments will always cause unintended consequences that may prove regrettable. Where possible, try to preserve existing water flows and estuary life. Give extra space to water where possible.

WORK COOPERATIVELY WITH AFFECTED COMMUNITIES. The Dutch polder system – named for the reclaimed land where most people live – brings community groups into the decision-making process on flood control measures, obliging all sides to search for common ground.

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Everything New Orleans

The Times-Picayune

Dutch ambassador tours the devastation

In trip with Landrieu, official pledges support for New Orleans

Tuesday, November 29, 2005

By Leslie Williams
Staff writer

Not quite a century ago, the Dutch turned to New Orleans as a source of state-of-the-art flood-control technology: the Wood screw pump still used to drain the city.

On Monday, it was turnabout as the Netherlands' ambassador to the United States toured flood-ravaged New Orleans.

The gesture was partly symbolic and sharply political: a signal to congressional naysayers that smart engineering can overcome even the most difficult water-management challenges, said U.S. Sen. Mary Landrieu, who escorted Boudewijn J. van Eenennaam on a bus tour that included St. Bernard Parish, eastern New Orleans and Lakeview.

Also aboard the bus was U.S. Assistant Secretary of the Army John Woodley Jr., who used the occasion to announce that at least the conceptual design of a strengthened flood-protection system for New Orleans should be roughed out by the spring. It probably will incorporate techniques used in the Netherlands that shield that country's coast from storm surge without affecting hydrology or navigation, Woodley said.

"The Dutch are the best in the world in terms of storm and flood-damage protection," Woodley said.

The conceptual design is an early step in a two-year, $8 million study that follows the corps' commitment to rebuild the levee system to pre-Katrina strength -- able to withstand the equivalent of a slow-moving Category 3 storm -- in time for the June 1, 2006, start of the next hurricane season. The study will explore the feasibility of strengthening flood defenses to resist a Category 5 storm.

Landrieu said she is not waiting for the study to be completed. She is pressing ahead in a campaign to persuade Congress to dedicate the money necessary for state-of-the-art protection, including restoration of wetlands between population centers and the Louisiana coast.

"We know it's going to cost billions of dollars, that's why we need the funding mechanism in place now," said Landrieu, who has long pressed Washington to give Louisiana a larger portion of the federal oil and gas revenue collected off Louisiana shores as a way to help pay for the projects.

The corps' conceptual design will identify alternatives for providing protection "in an environmentally responsible way," Woodley said.

The design alternatives will be reviewed by the public and Congress, which will decide what gets constructed, said Woodley, whose sister, Cecilia, was displaced from her Lakeview home by Katrina.

The Netherlands re-engineered its flood-protection system after a 1953 storm surge killed more than 1,800 people and displaced hundreds of thousands of residents. Its solution: the Delta Works, a $14.7 billion network of barriers, dams and other structures designed to repel North Sea waters.

Outlets of Lake Pontchartrain, including the Rigolets, could benefit from structures that remain open or out of the way until a storm surge threatens, Woodley said. One device, for example, rests at the bottom of the sea, then is inflated and rises when the coast is threatened. Another has wide gates that shut during a storm.

Two-thirds of the Netherlands is below sea level, Landrieu said, citing the country's experience as evidence of what can be done if the political will is there and money is provided.

"The Netherlands have done it," she said.

Making residents safe should be the first step, said van Eenennaam, who described the billions spent on flood protection as a sound investment based on what the protected areas contribute to the national economy. The New Orleans region is a major producer of seafood as well as oil and gas.

The ambassador said Dutch experts will continue to work closely with the United States as it seeks a solution.

Visits like the one arranged by Landrieu, he said, tell the story of devastation better than any reporting or photographs.

"It adds an emotional dimension," said van Eenennaam, adding that he empathized with Tiffany Bennett, a first-time homeowner in eastern New Orleans. The group visited the flood-damaged home of Bennett, who works as a page designer for The Times-Picayune.

Her home soaked in about 7 feet of water and Bennett said she is holding off on resettling in the neighborhood she adores until the city offers a plan of how it intends to redevelop the part of New Orleans east of the Industrial Canal and north of the Mississippi River-Gulf Outlet.

Van Eenennaam said he will report back to his country about "what is needed here and what we can offer in the Netherlands."

The Netherlands invested in a world-class flood-protection system, he said, because it decided after the 1950s disaster that "this will never happen again."

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